DYNAMIC HOLOGRAPHY USING PHOTOREFRACTIVE MATERIALS

APPLICATIONS TO 3D VISUALIZATION AND IMAGE PROCESSING

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holography metamaterials

Objective

The objective of this work is to numerically study the spatial evolution of Bragg and non-Bragg orders in iron doped photorefractive (PR) lithium niobate (LN:Fe) for different Gaussian beam profiles.

Motivation

PR materials can be used to record holographic data. It can be also used to implement dynamic real-time holographic interferometry (RHI).

Introduction

The refractive index (RI) of a PR material changes when it is illuminated by an interfering coherent light source due to the space charge field created inside the material. To implement RHI using PR materials, two beams (reference and object) are interfered on a PR material to write the hologram of the object. During the hologram writing process, Bragg and non-Bragg orders are formed, which can be used to implement Phase shifting Digital Holography.

Methodology

➢ Experiment

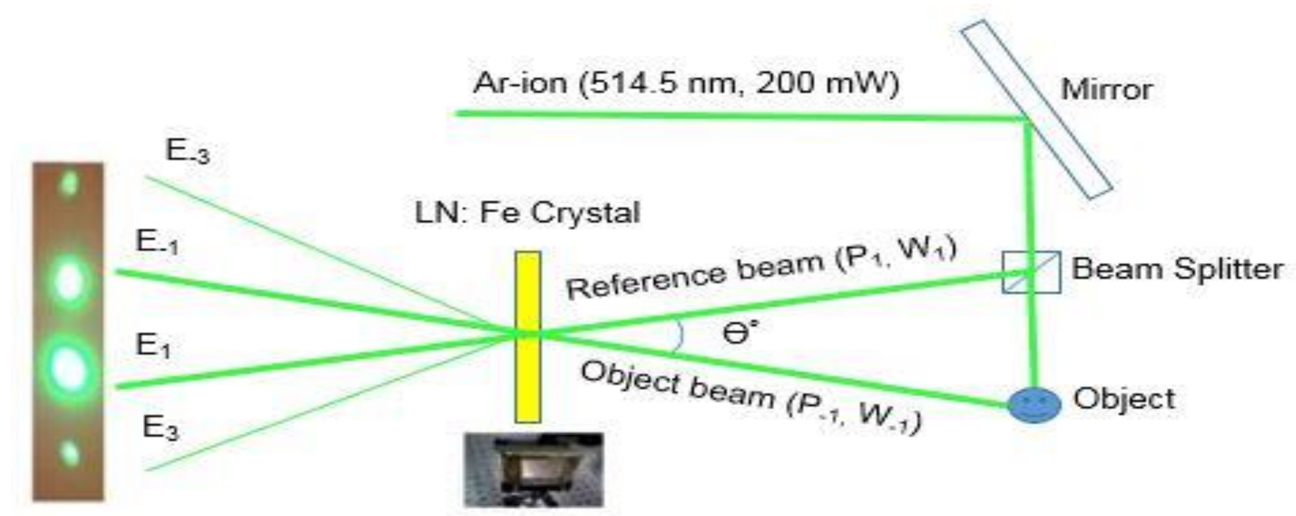
In the experimental part, a 514.5 nm Ar-ion laser beam with a power of approximately 200 mW is split into two parts, one serving as the reference, and one illuminating the object to form object beam. Both beams interact within a PR LN:Fe crystal and a grating is formed through the coupling of these two beams, which is responsible for self-diffraction giving rise to generation of Bragg and non-Bragg orders.

➢ Theory

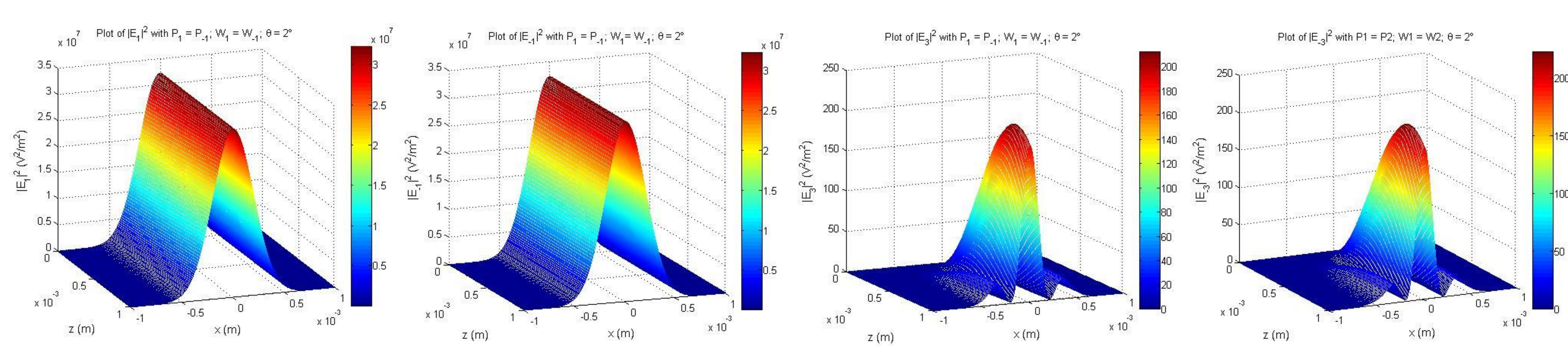
In the theoretical part, the spatial evolution equations of the Bragg and non-Bragg orders are derived in terms of the interactions between their angular plane wave spectra. The angular plane wave spectrum of an optical field is the Fourier decomposition of the field into plane waves traveling in various directions. The change in RI (Δn) is expressed in terms of total intensity (I) and the photovoltaic coefficient (c_1) of the PR material as

$$\Delta n = c_1 I$$

Experimental Setup

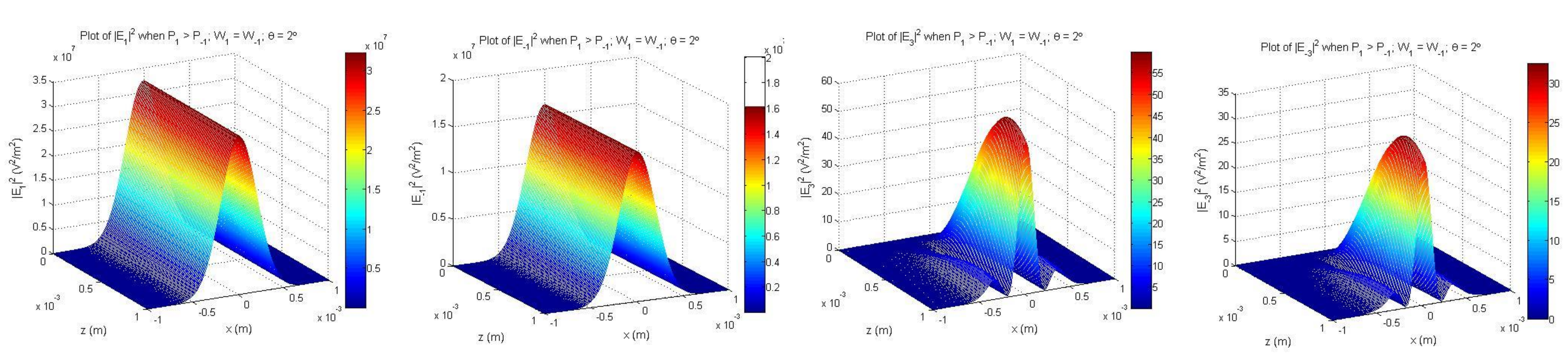


Simulation Results



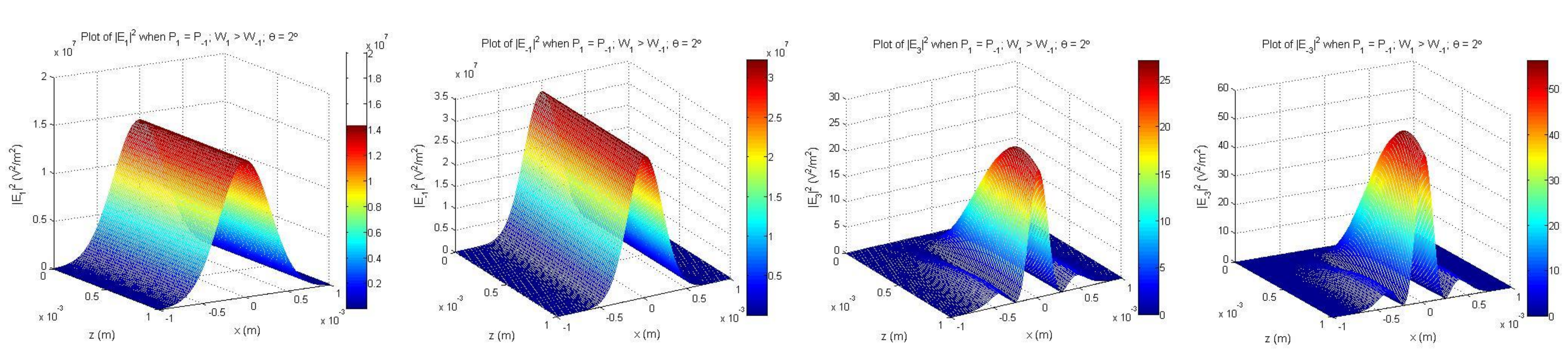
1(a) 1(b) 1(c) 1(d)

Figure 1(a)-1(d): Evolution of Bragg and non-Bragg orders for case (1).



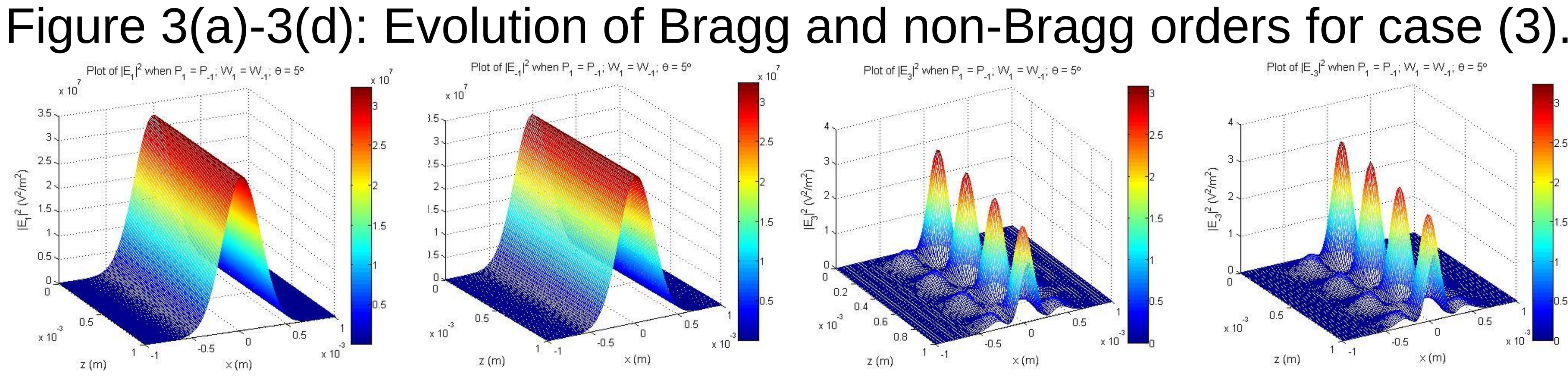
2(a) 2(b) 2(c) 2(d)

Figure 2(a)-2(d): Evolution of Bragg and non-Bragg orders for case (2).



3(a) 3(b) 3(c) 3(d)

Figure 3(a)-3(d): Evolution of Bragg and non-Bragg orders for case (3).



4(a) 4(b) 4(c) 4(d)

Figure 4(a)-4(d): Evolution of Bragg and non-Bragg orders for case (4).

Results and Discussion

- The solutions to the coupled differential equations governing the interactions of angular plane wave spectra of Bragg and non-Bragg orders are obtained numerically by solving them in MATLAB© for different types of Gaussian beam profiles.
- E_l where l = 1,-1,3,-3 denote optical fields for the l^{th} order along z axis as a function of transverse coordinate x. E_1, E_{-1} are Bragg orders. E_3, E_{-3} are non-Bragg orders.
- The evolution of Bragg and non-Bragg orders depends on incident beam parameters such as beam powers P_1, P_{-1} and waists W_1, W_{-1} along with angle Θ between the incident reference and object beams.
- Numerical simulations are performed for four different cases:
  (1) $P_1 = P_{-1}$ = 100 mW; $W_1 = W_{-1}$ = 0.4 mm; Θ = 2º
  (2) P_1=100 mW,P_{-1}=50 mW; W_1=W_{-1}=0.4 mm; Θ = 2º
  (3) P_1=P_{-1}=100 mW; W_1=0.6 mm,W_{-1}=0.4 mm; Θ = 2º
  (4) $P_1 = P_{-1}$ = 100 mW; $W_1 = W_{-1}$ = 0.4 mm; Θ = 5º
- When the powers and waists of the two incident beams are identical the optical field of the two Bragg orders and two non-Bragg orders at the exit plane of the crystal are also identical.
- When the optical field of first Bragg order E_1 is higher than second Bragg order E_{-1}, the optical field of first non-Bragg order E_3 is higher than second non–Bragg E_{-3} and vice versa.

Future Work

- Investigate the phenomena of the axial variation of non-Bragg orders along the crystal axis when the angle between the incident beams increases.
- Study the spatial evolution of Bragg and non-Bragg orders in a PR LN:Fe material for different beam profiles such as flattops numerically.

References

- P. Banerjee, G. Nehmetallah, U. Abeywickrema, S. Lyuksyutov, N. Kukhtarev, "Non-Bragg diffraction orders in holographic recording and its application to one-shot phase-shifting holographic interferometry," Proc. SPIE, **8644,** 864402-1 – 864402-9 **(**2013**).**
- U. Abeywickrema, P. Banerjee, "Phase-shifting holography using Bragg and non-Bragg orders in photorefractive lithium niobate," Proc. SPIE, **9200,** 1-8 (2014).